#9 #9

Fisheries Research Bulletin No. 9

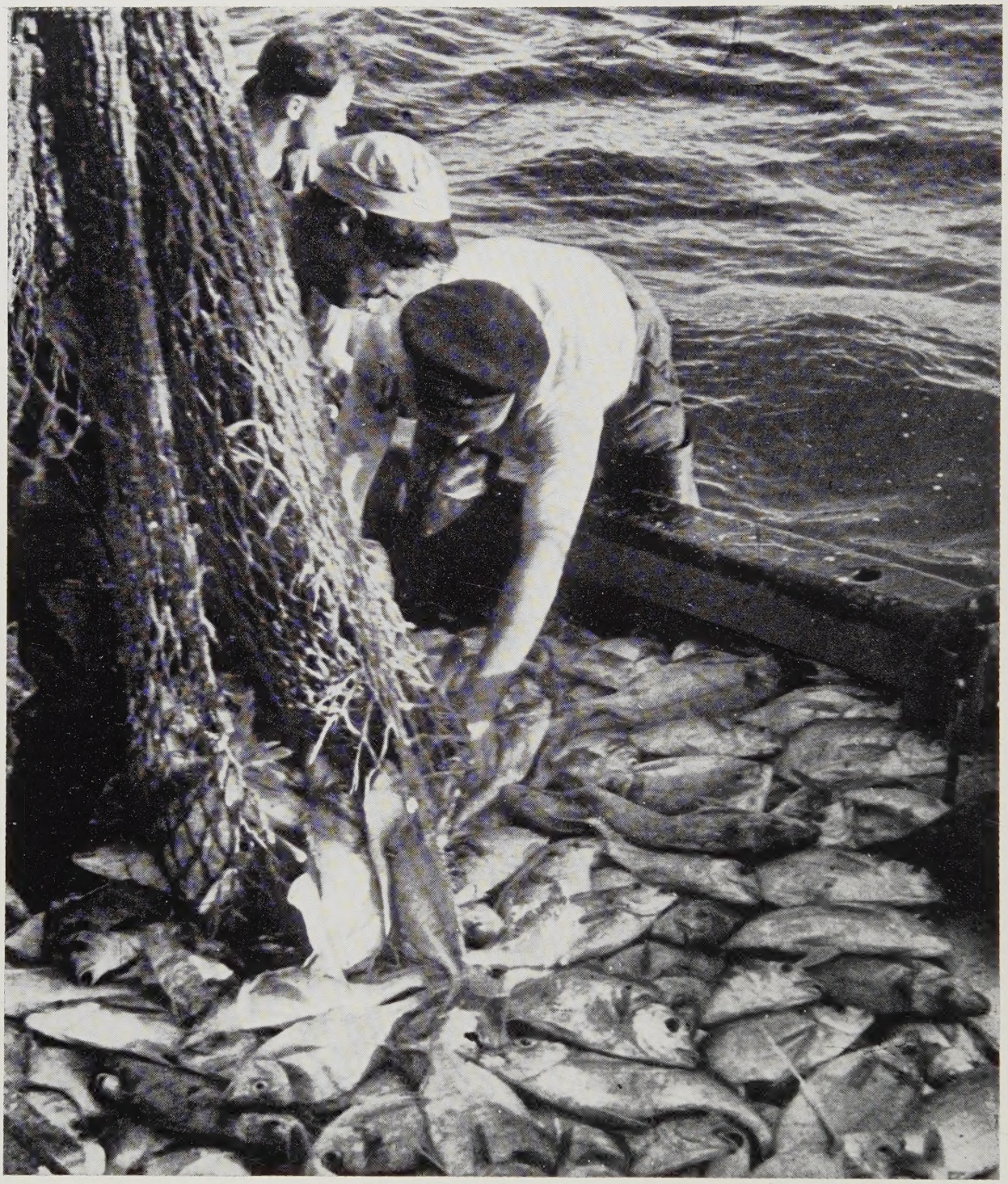
A Survey of the Tarakihi, *Cheilodactylus macropterus* (Bloch and Schneider), in the East Cape Area, New Zealand, 26-30 March 1971

By
C. M. Vooren and L. J. Tong

LIBRARY
JUL 6 1973
FISH & WILDLIFE SERVICE

Fisheries Research Division
New Zealand Ministry of Agriculture and Fisheries

A Survey of the Tarakihi,
Cheilodactylus macropterus
(Bloch and Schneider),
in the East Cape Area, New Zealand,
26-30 March 1971



[Photograph by M. K. McKenzie

A good tarakihi catch in the East Cape area on the deck of r.v. *Ikatere* off Gable End Foreland.

Fisheries Research Bulletin No. 9

A Survey of the Tarakihi, *Cheilodactylus macropterus* (Bloch and Schneider), in the East Cape Area, New Zealand, 26-30 March 1971

By

C. M. Vooren and L. J. Tong,

Fisheries Research Division, Ministry of Agriculture and Fisheries, Wellington, New Zealand

Fisheries Research Division

New Zealand Ministry of Agriculture and Fisheries

Published by the New Zealand Ministry of Agriculture and Fisheries
Wellington
1973

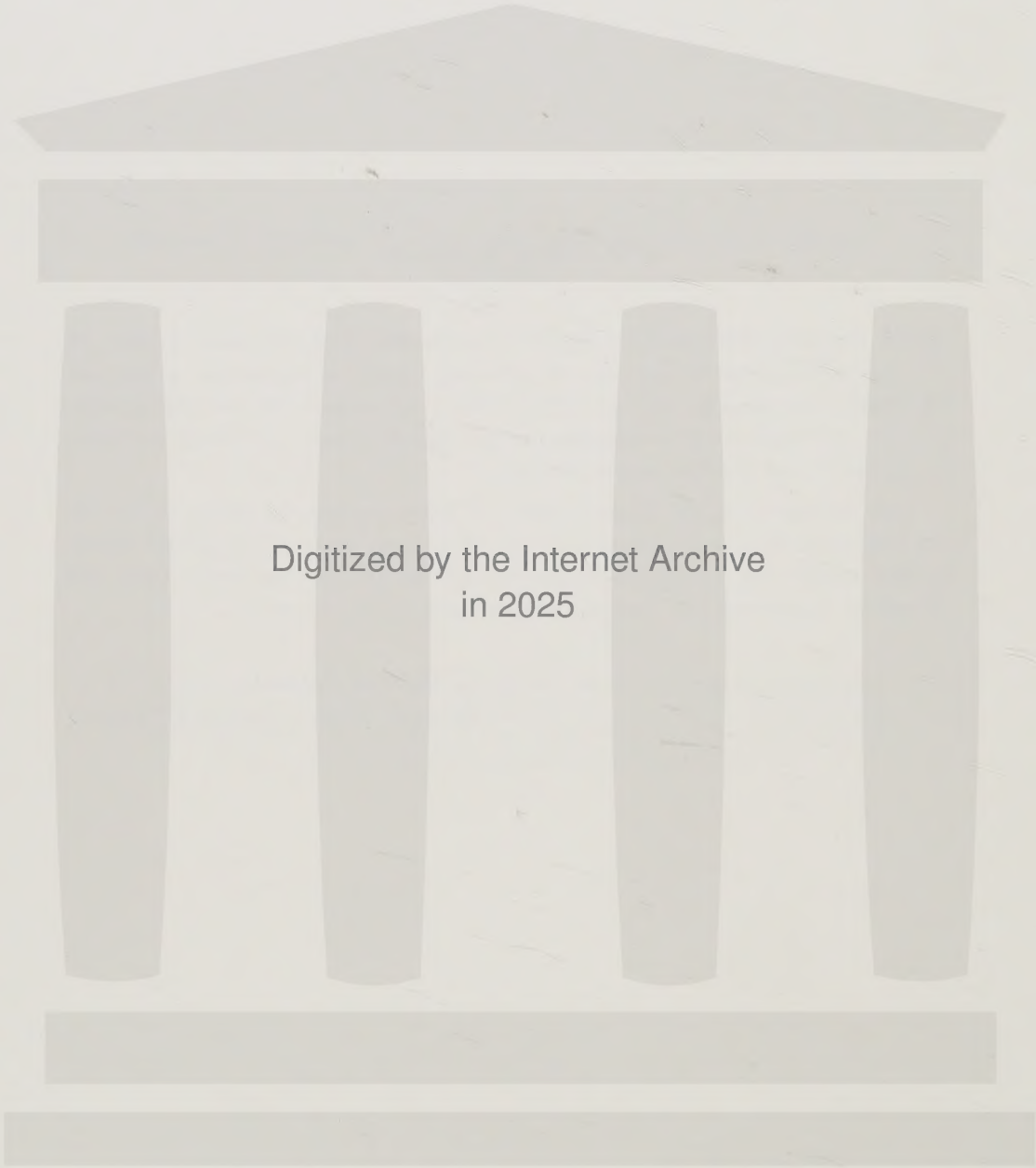
This series of research bulletins, which was begun in 1968, was formerly published by the New Zealand Marine Department before the Fisheries Research Division was transferred from that Department to the Ministry of Agriculture and Fisheries in September 1972.

FOREWORD

THE narrowness of the New Zealand Continental Shelf and lack of data on the productivity of our near-shore waters make it imperative to provide information on demersal fish production. With such data it will become possible to guide and control the development of the fishing industry so that it continues to operate at an effective economic level.

This bulletin by C. M. Vooren and L. J. Tong provides an estimation of the standing stock of a single species on part of the east coast of the North Island. Further studies will furnish additional information on the sustainable yield and provide a foundation for rational management of the resources.

G. DUNCAN WAUGH,
Director, Fisheries Research Division.



Digitized by the Internet Archive
in 2025

https://archive.org/details/new-zealand-fisheries-research-bulletin_1973_9

FIGURES

Page

1. The study area, showing depth zones, subzones A to H, and trawl stations 087 to 159 10
2. Relationship between catch rate and depth for tarakihi and snapper 13
3. Tarakihi catch rate and bottom temperature in the deep zone at trawl stations 087 to 159 14
4. Age composition of the samples 15
5. Age composition of the sexes and of the total population 16
6. Sex ratio of length groups and comparison between total length frequency of surveyed population and of commercial catches 17
7. Growth curves of tarakihi in the East Cape area 19
8. Length composition of age groups 5 to 8 20
9. Regression of l_{t+1} on l_t for age groups 5 to 15 21
10. Frequency distribution of maturity stages, from the weighted combined data for all catches 23

TABLES

Page

1. Trawl stations in East Cape area, 26–30 March 1971 11
2. Relationship between average catch rate and depth for the major species 14
3. Catch rate and density index of tarakihi in East Cape area, March 1971 14
4. Percentage of males in the individual samples 18
5. Age composition, mean length, mean weight, sex ratio, and density index of the age groups 18
6. Analysis of variance of length-at-age between sexes 19
7. Values of the parameters K and L_∞ of the von Bertalanffy growth equation 21
8. Individual estimates and mean of t_0 22

9A. Relationship between length and maturity 24

9B. Relationship between age and maturity 24

CONTENTS

	Page
INTRODUCTION	9
METHODS AND DEFINITIONS	11
DISTRIBUTION AND ABUNDANCE OF SPECIES	13
AGE COMPOSITION	15
SEX RATIO	18
GROWTH	19
SPAWNING	23
AGE AND LENGTH AT FIRST MATURITY	24
DISCUSSION	25
SUMMARY	26
REFERENCES	27

INTRODUCTION

The Continental Shelf between Mahia Peninsula and Cape Runaway (Fig. 1) is one of the major tarakihi fishing areas of New Zealand; all suitable bottom in this area is fished commercially by motor trawlers. Since 1960 the tarakihi catch per unit of fish effort has declined considerably there, which reflects a decline in the abundance of the exploitable phase of the stock (Vooren in press). To provide a basis for investigations into the nature and causes of this decline, the distribution and abundance of the tarakihi were determined by a trawl survey, and data on the dynamics of the population were collected.

The largest catches of tarakihi in this area are normally taken during late summer-autumn (Vooren in press), which coincides with the spawning season (McKenzie 1961, Tong 1972a). Therefore the area was surveyed in late March to sample the whole spawning stock and to obtain data on the reproductive biology.

There is no information at present to suggest the existence of stock boundaries within the East Cape area. It is therefore assumed that the area contains one unit stock of tarakihi.

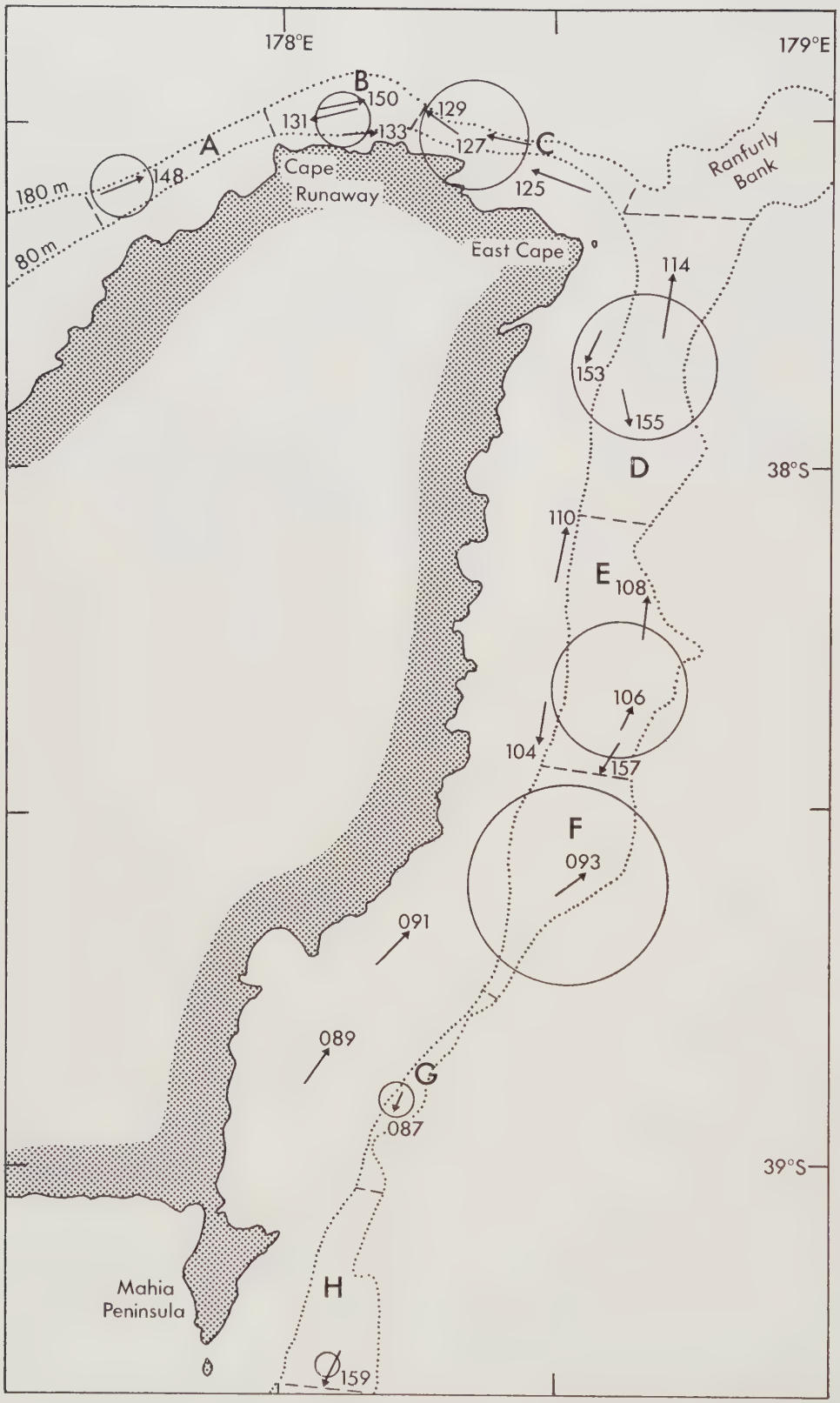


Fig. 1: The study area, with depth zones, subzones A to H. and trawl stations 087 to 159. The area of the circles indicates the relative magnitude of the density index (in number per hectare) of the tarakihi in the subzones of the deep zone.

METHODS AND DEFINITIONS

The area shown in Fig. 1 is here designated as the East Cape area. This area was surveyed from 26 to 30 March 1971 by the research vessel *James Cook*, a diesel-powered stern trawler of 42.2 m overall length, 552.8 gross tons, and 1,200 bhp. A Granton trawl was used with ground rope of 36.6 m and sweeps of 73.2 m; the net was fitted with 18 bobbins of 46-cm diameter and 50 floats of 20-cm diameter. The mesh size of the cod-end was 11.4 cm. and a cod-end liner with a mesh size of 3.8 cm was used. The average towing speed was about 8.2 km per hour (ground speed). During trawling the headline was about 1.8 m from the bottom, and the distance between the doors was estimated at 56 m.

A total of 20 trawl shots was made, 2 of 30 min, 1 of 50 min, and 17 of 60 min duration (Table 1). Except for those at stations 150 and 159 all trawl shots were made in the daytime. The trawl shots covered two depth zones: 6 shots at depths between 40 and 70 m (shallow zone) and 14 shots at depths between 90 and 160 m (deep zone; see Table 1 and Fig. 1). The Ranfurly Bank, an extension of the Continental Shelf north-east of East Cape, consists mostly of very rough bottom unsuitable for trawling, and this area was therefore not surveyed.

The trawl catches were sorted according to species, and the fish were counted and put into boxes. The weight of the catch of each species was roughly estimated from the number of boxes caught, the boxes being so designed that they contained on the average 45 kg of fish when full. Water temperatures were measured at the end of each trawl shot with a bathythermograph, reversing thermometer, and ordinary thermometer.

Stratified random sampling has often been found to be a more efficient method for dealing with catches than simple random sampling (for example, Gulland 1955, Pinhorn and Fleming 1965), but this is not true for catches of sexually mature tarakihi. In these fish the length compositions of the age groups overlap to a high degree, so that the variance of the age within all length groups is usually very high (see page 20). Under such conditions stratified random sampling by taking a fixed small number of fish from each length group offers no advantages when accurate estimates of the age composition of catches and of the mean length of the more abundant age groups are wanted. When many age groups are represented in narrow length strata, such sampling results in large errors in the estimates of the age compositions of the strata, and these errors are then multiplied by the weighting factors that are used to relate the stratum data to the total catch. Theoretically, the sample size required to estimate accurately the age composition of one stratum under such conditions is equal to the sample size required to estimate with the same accuracy the age composition of the catch as a whole by a simple random sample. Catches were therefore sampled for length, age, sex, and gonad state in a simple random manner.

Altogether five samples of slightly over 100 fish and two samples of 57 and 62 fish respectively were collected. The latter two samples represent total catches.

Pearson and Heartley (1954) show a chart providing the 95 percent confidence interval of estimates of proportions in binomial sampling at various

TABLE 1: Trawl stations in East Cape area, 26-30 March 1971, cruise J.04/71

Station No.	Date	Position Start	Position Finish	Average depth (m)
087	26/3/71	38° 55′ S, 178° 13′ E	38° 57′ S, 178° 12′ E	116
089	26/3/71	38° 53′ S, 178° 02′ E	38° 50′ S, 178° 05′ E	48
091	26/3/71	38° 43′ S, 178° 10′ E	38° 40′ S, 178° 14′ E	49
093	26/3/71	38° 37′ S, 178° 30′ E	38° 35′ S, 178° 33′ E	145
104	27/3/71	38° 20′ S, 178° 29′ E	38° 24′ S, 178° 28′ E	64
106	27/3/71	38° 23′ S, 178° 37′ E	38° 21′ S, 178° 38′ E	122
108	27/3/71	38° 15′ S, 178° 39′ E	38° 11′ S, 178° 40′ E	125
110	27/3/71	38° 10′ S, 178° 30′ E	38° 05′ S, 178° 31′ E	69
114	27/3/71	37° 49′ S, 178° 42′ E	37° 41′ S, 178° 44′ E	123
125	28/3/71	37° 36′ S, 178° 33′ E	37° 34′ S, 178° 27′ E	41
127	28/3/71	37° 32′ S, 178° 27′ E	37° 31′ S, 178° 22′ E	111
129	28/3/71	37° 31′ S, 178° 19′ E	37° 29′ S, 178° 16′ E	129
131	28/3/71	37° 29′ S, 178° 08′ E	37° 30′ S, 178° 03′ E	136
133	28/3/71	37° 31′ S, 178° 06′ E	37° 31′ S, 178° 10′ E	98
148	29/3/71	37° 36′ S, 177° 41′ E	37° 34′ S, 177° 46′ E	132
150	29/3/71	37° 29′ S, 178° 04′ E	37° 29′ S, 178° 07′ E	155
153	30/3/71	37° 48′ S, 178° 35′ E	37° 51′ S, 178° 33′ E	68
155	30/3/71	37° 53′ S, 178° 37′ E	37° 56′ S, 178° 38′ E	121
157	30/3/71	38° 24′ S, 178° 37′ E	38° 27′ S, 178° 35′ E	121
159	30/3/71	39° 16′ S, 178° 07′ E	39° 19′ S, 178° 05′ E	129

sample sizes. At sample size 100 the 95 percent confidence interval of an estimate of a proportion p of 50 percent is between 40 and 60 percent. Lower or higher estimates have narrower confidence intervals; for example, for an estimate of p of 10 percent, the confidence interval is between 5 and 18 percent. This accuracy was considered satisfactory.

Fish length was measured to the tail fork and rounded off to the nearest whole centimetre below the actual length. The structure of the otoliths was identical to that described for tarakihi otoliths from the Bay of Plenty and was therefore interpreted in the same way in terms of age (Vooren and Tong 1972). Spawning in the East Cape area takes place in March-April; therefore 1 March was adopted as the birth date of the year classes. Since the samples were collected in March, the numbers of the age groups also indicate the age of the fish in years.

The gonads were classified according to the maturity stages described by Tong (1972a). Previous work showed that a maturity stage analysis should be supplemented by histological observations on the ovaries (Tong 1972b) to determine the presence of evacuated follicles and so provide a measure of the number of recently spawned females among those normally classified as stage 4 or mature. Fifty-four ovaries were therefore sectioned from three stations.

The swept area is defined as the product of the distance between the trawl doors and the distance towed by the trawl; the area swept per hour of trawling was therefore about 40.32 hectares. The density index is the number or quantity of fish caught per hectare of swept area, and the catch rate is the number or quantity of fish caught per hour of trawling.

The six trawl stations in the shallow zone were evenly spaced (Fig. 1). The mean catch rate for this zone was therefore estimated by the arithmetic mean of the measurements taken at the trawl stations.

The stations in the deep zone were unevenly distributed. To enable calculation of means for the deep zone as a whole, the zone was divided into eight subzones A to H (Fig. 1), each sampled by one isolated trawl station or by a cluster of stations. In the absence of detailed data on distribution it is assumed that the proportion of potential tarakihi habitat is the same in all subzones. Subzones A, B, C, G, and H were roughly equal in surface area. Subzones D, E, and F were similar in size and were each about twice as large as the average of the five other zones (Fig. 1). The five smaller zones were therefore allocated a surface factor of 1 and the three larger zones a surface factor of 2. The mean catch rate and density index in a subzone with a cluster of stations were estimated by the arithmetic mean of the station measurements, and the mean of the deep zone as a whole was estimated by the arithmetic mean of the subzone means weighted by the surface factors.

Sufficiently large tarakihi samples for age and growth analysis were obtained only in the deep zone. The samples varied in size, and there were considerable differences in the age composition and the abundance of the tarakihi between the subzones. More and larger samples were obtained in the subzones with greater fish abundance. To obtain unbiased means of the various population parameters for the deep zone as a whole, the data of each sampling station were therefore weighted by the sample size, the abundance in the subzone, and, for the clusters of stations, by the ratio between station catch and total catch in the subzone. The weighting factor for the abundance in each subzone was the product of the surface factor and the catch rate (in number per hour).

The terms vulnerability, recruitment, annual growth rate, annual mortality rate, and instantaneous mortality rate are used in the present study in the sense defined by Ricker (1958). Since bottom trawling is virtually the only commercial fishing method for tarakihi in the East Cape area (Vooren in press), vulnerability refers to trawl gear only. The "strength" of a year class is the ratio of its abundance at any age to the average abundance of year classes at that age within the same stock.

DISTRIBUTION AND ABUNDANCE OF SPECIES

The 11 species listed in Table 2 comprised 87 percent of the catches by weight. Tarakihi was the species with the highest average catch rate, followed by snapper, horse mackerel, barracouta, and trevally. Tarakihi and snapper were almost mutually exclusive in their occurrence, and this was clearly a function of their depth distribution, snapper occupying the shallow zone (40 to 70 m) and tarakihi the deep zone (90 to 160 m; see Fig. 2). A similar pattern has been observed in the Bay of Plenty (Tong and Elder 1968). The catch rate of the other major species was also clearly a function of depth (Table 2). Tarakihi formed 48 percent of the average hourly catch (by weight) in the deep zone, and snapper made up 30 percent of the same catch in the shallow zone. The higher total catch rate in the shallow zone resulted chiefly from the high abundance of horse mackerel, barracouta, and trevally; these three species accounted for 46 percent of the average hourly catch in the shallow zone.

The catch rates of tarakihi at individual trawl stations in the deep zone ranged between 0 and 589 kg per hour, and between 0 and 844 fish per hour. The fish density varied considerably between the subzones (Fig. 1, Table 3). The catch rates were highest between East Cape and latitude 38° 40′ S; further south the species was virtually absent.

The bottom temperature of the stations in the deep zone ranged between 12.6 and 16.2°C. There was no clear relationship between bottom temperature and tarakihi catch rate, small or zero catches being made throughout the range of temperatures (Fig. 3).

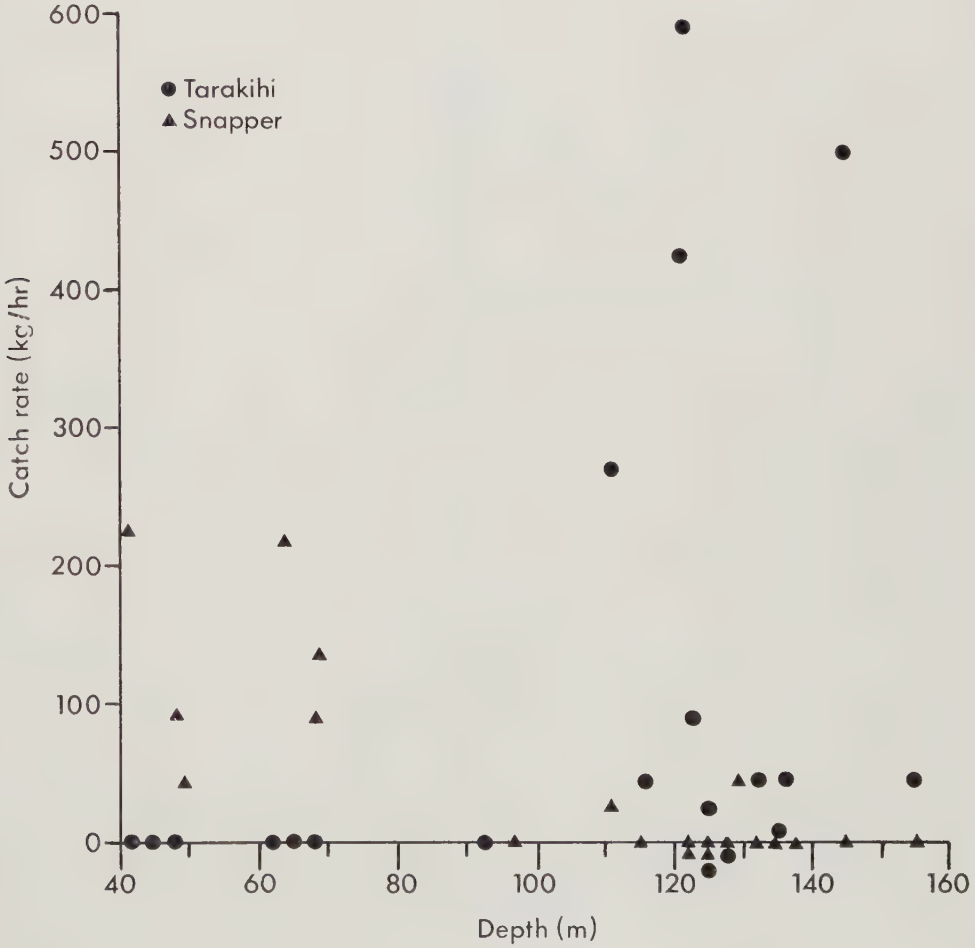


Fig. 2: Relationship between catch rate and depth for tarakihi and snapper.

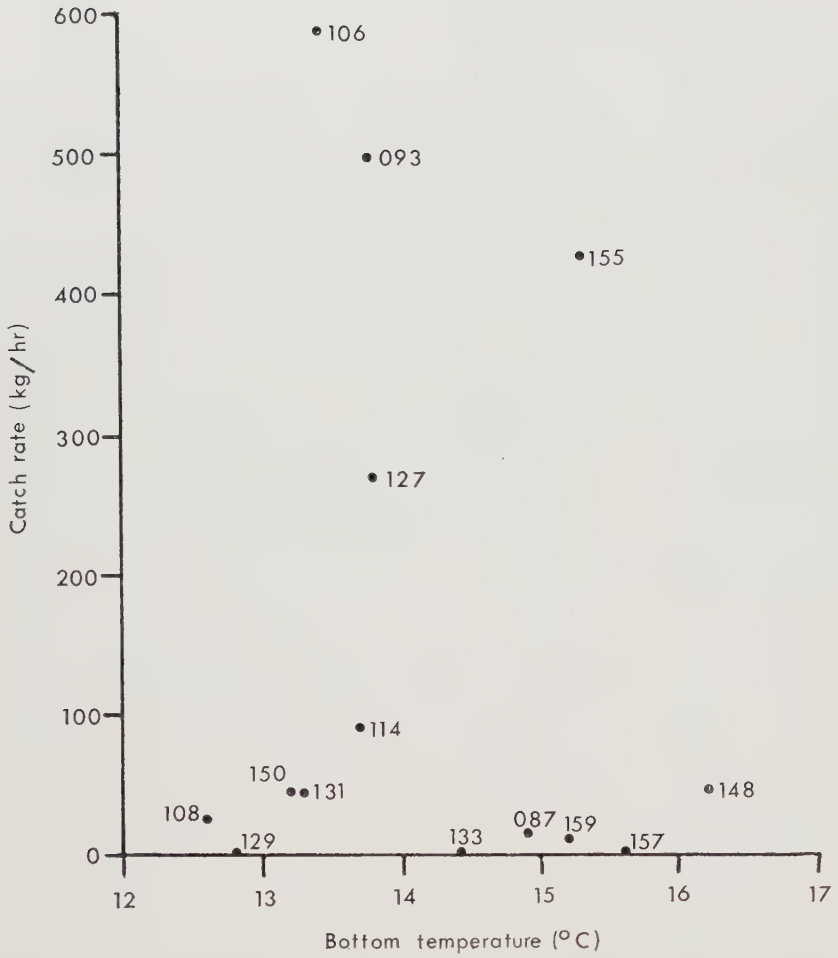


Fig. 3: Tarakihi catch rate and bottom temperature in the deep zone at trawl stations 087 to 159.

TABLE 2: Relationship between average catch rate (kg/hr) and depth for the major species

Species	Shallow zone (40-70 m)	Deep zone (90-160 m)
Tarakihi *(Cheilodactylus macropterus)*	*	197
Frostfish *(Lepidopus caudatus)*	*	14
Southern kingfish *(Jordanidia solandri)*	*	29
School shark *(Galeorhinus australis)*	*	15
Horse mackerel *(Trachurus novaezelandiae)*	85	24
Barracouta *(Thyrsites atun)*	72	34
Trevally *(Caranx lutescens)*	49	*
Snapper *(Chrysophrys auratus)*	134	4
Red gurnard *(Chelidonichthys kumu)*	22	*
Kahawai *(Arripis trutta)*	19	*
Yellowtail *(Seriola grandis)*	17	3
Others	49	40
Totals	447	360

* Negligible quantities.

TABLE 3: Catch rate and density index of tarakihi in East Cape area, March 1971

Subzone	Station Nos.	Catch rate kg/hr	Catch rate No./hr	Density index kg/hectare	Density index No./hectare
A	148	45	57	1.12	1.41
B	131, 133, 150	30	43	0.74	1.07
C	127, 129	136	174	3.37	4.32
D	114, 155	261	327	6.47	8.11
E	106, 108, 157	204	293	5.06	7.27
F	093	499	627	12.38	15.55
G	087	15	22	0.37	0.55
H	159	9	10	0.22	0.25
	Means	197	255	4.88	6.31

AGE COMPOSITION

The age of the fish in the samples ranged from 3 to 27 years. The individual age samples fall clearly into two categories: age group 6 dominated strongly between Cape Runaway and latitude 38° S (stations 150, 127, 114, and 155), and age group 7 did so in the remainder of the area (stations 148, 106, and 093; see Fig. 4). The overall age-frequency distribution forms a unimodal curve, the mode occurring at the age of 7 years (Fig. 5). Apart from an abrupt decrease between age groups 7 and 8, the upward and the downward slopes of the curve are fairly smooth. The main irregularity in the distribution is the fairly high proportion of 15-year-olds, but this occurred only in the males and is probably a result of errors in the age determination.

The decrease in numbers from age groups 8 to 17 follows a smooth curvilinear pattern, which suggests that recruitment has been uniform in the year classes 1955 to 1964. The pattern of the abundance of the earlier age groups can be interpreted in different ways. Age groups 4 and 5 were clearly only partially present in the area, but age group 6 may have been either a weak but fully represented year class or a partially represented year class of average strength.

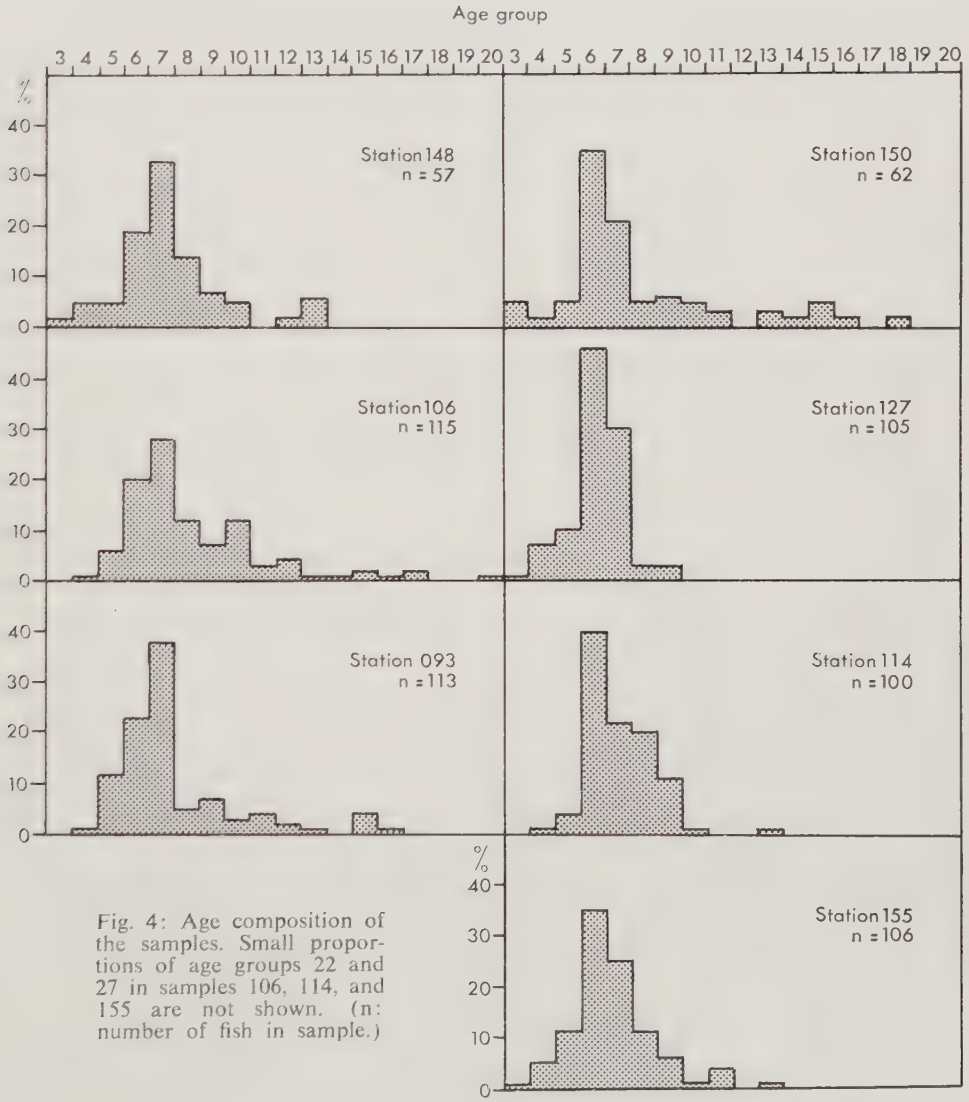


Fig. 4: Age composition of the samples. Small proportions of age groups 22 and 27 in samples 106, 114, and 155 are not shown. (n: number of fish in sample.)

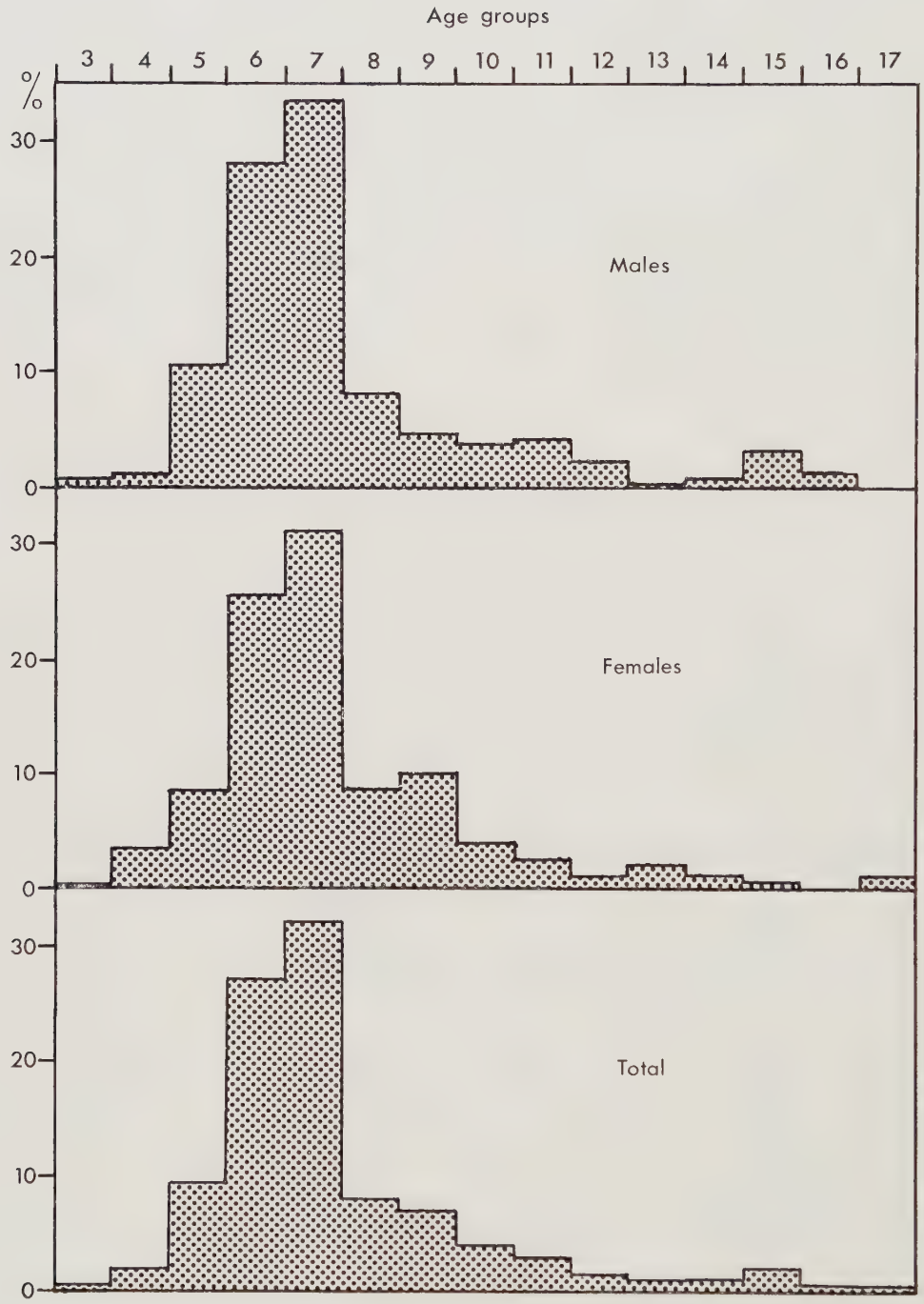


Fig. 5: Age composition of the sexes and of the total population. Small percentages of age groups 18, 20, 22, and 27 (all females) are not shown (see Table 5).

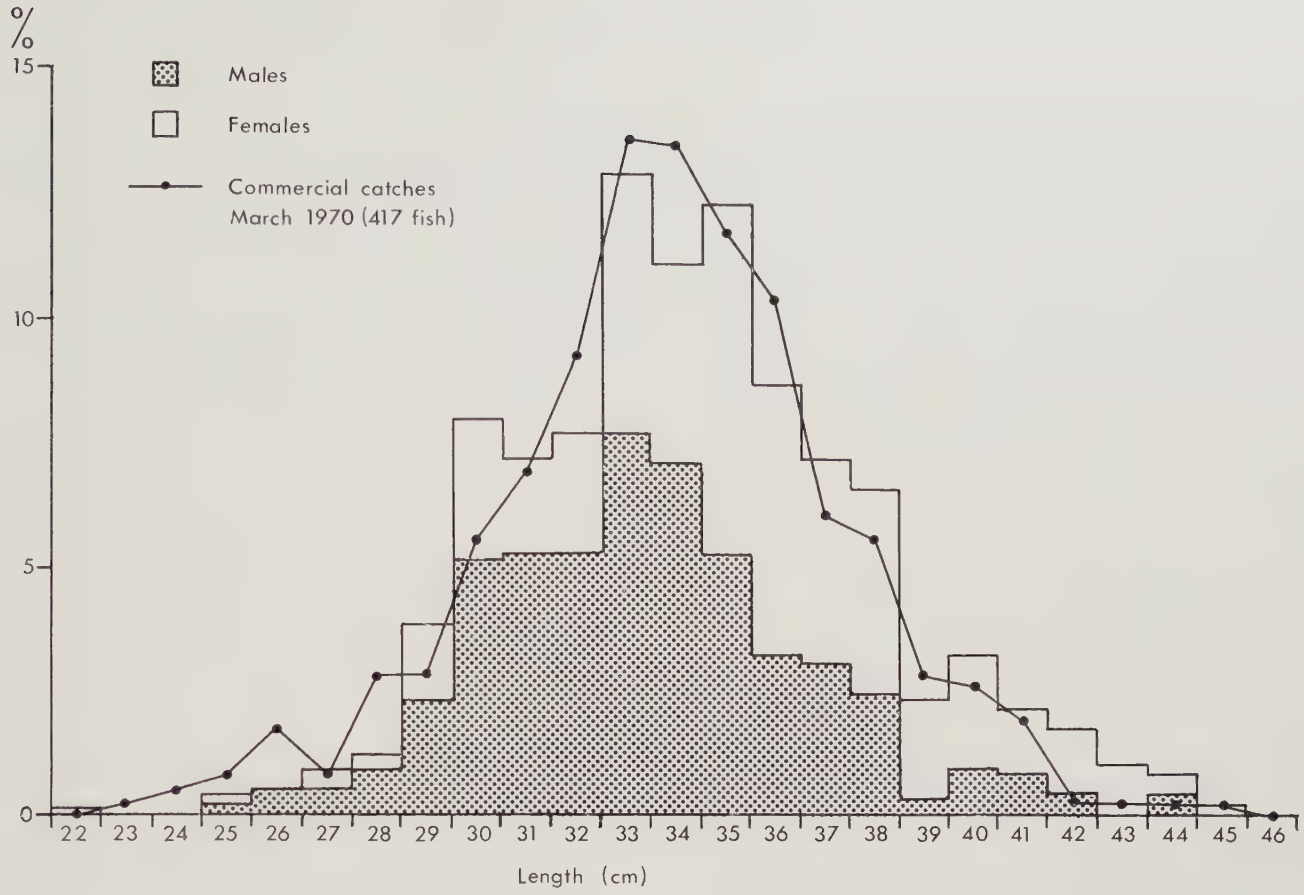


Fig. 6: Sex ratio of length groups and comparison between total length frequency of surveyed population (histogram) and of commercial catches (graph).

There were more fish of 17 years and older in the females, but the abundance of these age groups was so low that this had little influence on the total age composition of the sexes. The overall age-frequency distributions of the males and females were very similar. This suggests that the annual mortality rates of the sexes are similar.

Fish of 3 and 4 years old occurred only in very small numbers. A similar scarcity of juveniles up to 4 years old was also found in October 1969, when the area between East Cape and latitude 38° 30′ S was surveyed at depths between 14 and 70 m, five trawl shots of 1 hr in duration being made with the same trawl gear as was used in the present investigation. This virtual absence of small juveniles from the trawling grounds seems to be a persistent feature of the East Cape area, a feature also noted in the Bay of Plenty (Tong and Elder 1968). As a result, few fish of sizes below the legal minimum of 25 cm can be caught in these areas; during the present survey such fish comprised less than 1 percent of the total catch (Fig. 6). The results of line fishing in the study area (not including the Ranfurly Bank) in the course of tagging experiments in 1971 have shown that juveniles do not occur abundantly on the rough ground either (C. M. Vooren unpublished data). Therefore unless the juveniles occur on the Ranfurly Bank, there is no nursery ground in the East Cape area. The nearest locality where small juveniles have occasionally been caught in significant numbers is southern Hawke Bay (Vooren and Tong 1972).

SEX RATIO

The weighted mean percentage of males was estimated at 52 (± 9, with 95 percent confidence), so that the sex ratio was not significantly different from unity in the population as a whole. However, the percentage of males differed significantly from 50 in five out of the seven individual samples, ranging between 14 and 81 (Table 4). This uneven distribution of the sexes, which has also been observed in the Bay of Plenty (Tong 1972a) suggests that separate schools of males and females exist in autumn.

TABLE 4: Percentage of males in the individual samples, with 95 percent confidence limits

Station No.	% males
148	33 ± 12
150	81 ± 10
127	48 ± 10
114	35 ± 9
155	14 ± 1
106	41 ± 9
093	74 ± 8

The females dominated in some of the less abundant age groups, but in view of the small sample sizes for these age groups, this does not suggest a significant departure from a 1 : 1 sex ratio. In each of the more abundant age groups, 5 to 8, the sex ratio was close to unity (Table 5). The data on the sex ratio of the age groups therefore support the conclusion that the annual mortality rates of the sexes are similar (see page 17).

These results differ from those obtained in the Bay of Plenty (Tong 1972a), where a different mortality rate for the sexes was inferred because of a differing age at first maturity. These results were, however, based on a much smaller sample size and may not be significant. The fact that he may have been dealing with a different stock must also be considered.

TABLE 5: Age composition, mean length, mean weight, sex ratio, and density index of the age groups (weighted estimates)

Age group	Males %	Males Length (cm)	Males n	Females %	Females Length (cm)	Females n	Both sexes %	Length L(1) (cm)	Length L(2) (cm)	Weight (g)	n	% males in age group	Density index (number/ hectare)
3	0.5	—	4	0.2	—	2	0.4	23.2	—	—	6	—	0.02
4	1.0	—	8	3.3	—	12	2.1	29.3	—	—	20	24.7	0.13
5	10.6	—	27	8.7	—	24	9.7	30.3	30.3	528	51	54.9	0.61
6	28.0	32.1	102	25.7	33.6	104	26.9	32.8	32.9	680	206	52.5	1.69
7	33.6	33.3	90	30.8	35.4	100	32.2	34.3	34.4	783	190	52.3	2.03
8	7.9	35.6	23	8.5	36.3	41	8.2	36.0	36.0	898	64	49.2	0.52
9	4.5	34.1	13	10.1	38.0	33	7.2	37.0	36.1	945	46	29.6	0.45
10	3.5	36.8	11	3.8	39.3	12	3.7	38.1	38.1	1,070	23	47.8	0.23
11	4.0	36.8	6	2.3	40.7	8	3.2	38.2	38.7	1,105	14	62.6	0.20
12	1.9	38.4	3	0.9	41.2	4	1.4	39.2	39.8	1,195	7	67.6	0.09
13	0.2	38.4	3	1.8	42.4	6	1.0	41.9	40.4	1,362	9	8.6	0.06
14	0.4	39.5	2	1.1	43.0	2	0.8	42.0	41.3	1,413	4	25.8	0.05
15	3.2	42.2	5	0.4	45.7	2	1.8	42.6	43.9	1,588	7	87.8	0.12
16	0.8	41.9	2	0	—	0	0.4	41.9	—	—	2	—	0.03
17	0	—	0	0.8	44.5	2	0.4	44.5	—	—	2	—	0.02
18	0	—	0	0.4	42.0	2	0.2	42.0	—	—	2	—	0.01
20	0	—	0	0.4	47.0	1	0.2	47.0	—	—	1	—	0.01
22	0	—	0	0.4	48.0	1	0.2	48.0	—	—	1	—	0.01
27	0	—	0	0.4	53.0	1	0.2	53.0	—	—	1	—	0.01

Dash : No estimate made.

n : Number of fish in the samples.

For explanation of L(1) and L(2) see page 20.

GROWTH

Since the samples were collected in March, the mean lengths of the age groups represent the sizes reached at the end of the first of the two annual growth periods (Vooren 1972).

An analysis of variance of the length of the four most abundant age groups showed that in fish of 6 years and older the difference in length between males and females was significant (Table 6). Figure 7 shows that the difference in length between the sexes increases with age, which reflects a difference in growth rate. From the age of 6 years onward, growth rate decreases more rapidly in males than in females. A similar divergence of growth rates has been recorded for the Bay of Plenty, where it was attributed to an earlier age at first maturity in the males (Tong 1972a). However, in the East Cape area the first maturity is attained at the same age in both sexes (see page 24). For this region the difference in growth rate between the sexes indicates only that the attainment of sexual maturity affects the growth rate of the sexes differently.

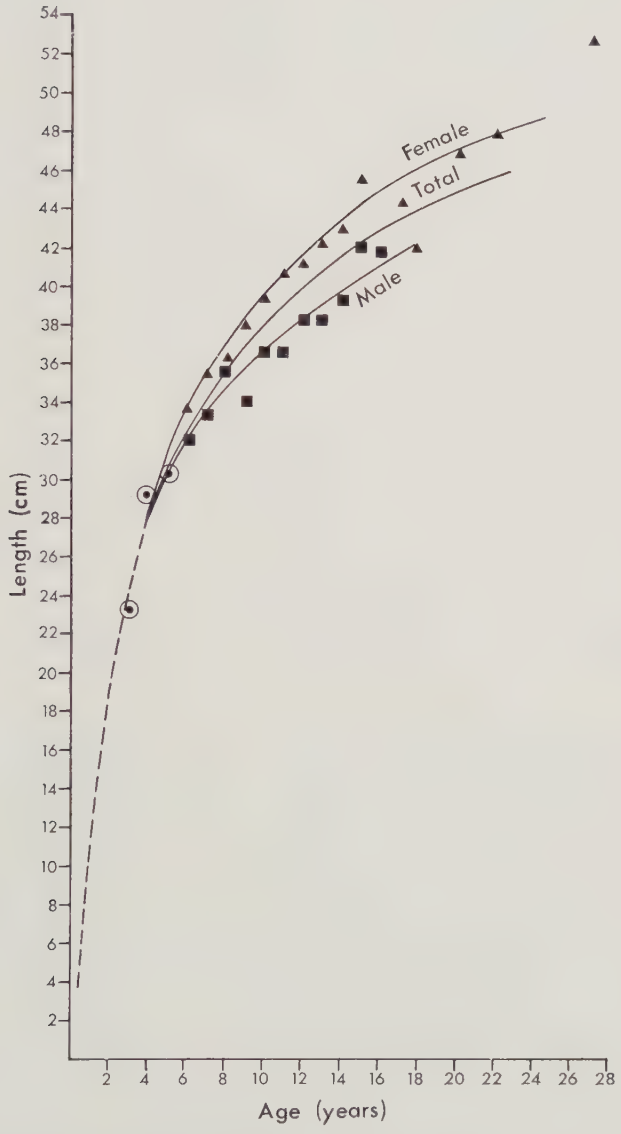


Fig. 7: Growth curves of tarakihi in the East Cape area.

TABLE 6: Analysis of variance of length-at-age between sexes

Age group	F			
5	2.0186	at 1 and	65	degrees of freedom
6	10.5141**	at 1 and	248	degrees of freedom
7	56.2675**	at 1 and	223	degrees of freedom
8	4.5449*	at 1 and	74	degrees of freedom

* 5% significance.
** 1% significance.
F: variance ratio.

Figure 6 states quantitatively what is commonly noticed when tarakihi catches in the field are sampled, namely, that the smaller fish are predominantly males and the larger fish mostly females. This is the combined effect of the even sex ratios of the age groups and the similar mortality rates but different growth rates of the sexes. The length groups in the lefthand side of the overall distribution contain the smaller members of age groups 6, 7, and 8 (see also Fig. 8), and among these the males dominate because of their lower growth rate. At any given size on the righthand side of the distribution the males are for the same reason older and therefore less abundant than the females.

The length-frequency distributions of age groups 5 to 8 were unimodal and symmetrical (Fig. 8). If the true length-frequency distributions of these age groups were different, for instance, polymodal or strongly skewed, errors in the age determination would be unlikely to be made so precisely that unimodal and symmetrical distributions would result. These results therefore provide further evidence for the validity of the interpretation of the otoliths described by Vooren and Tong (1972). Furthermore Fig. 8 shows that the length-frequency distributions of the age groups 5 and older overlapped to a large extent. This is also illustrated by the fact that the 34-cm length group in the samples contained fish from 5 to 13 years old.

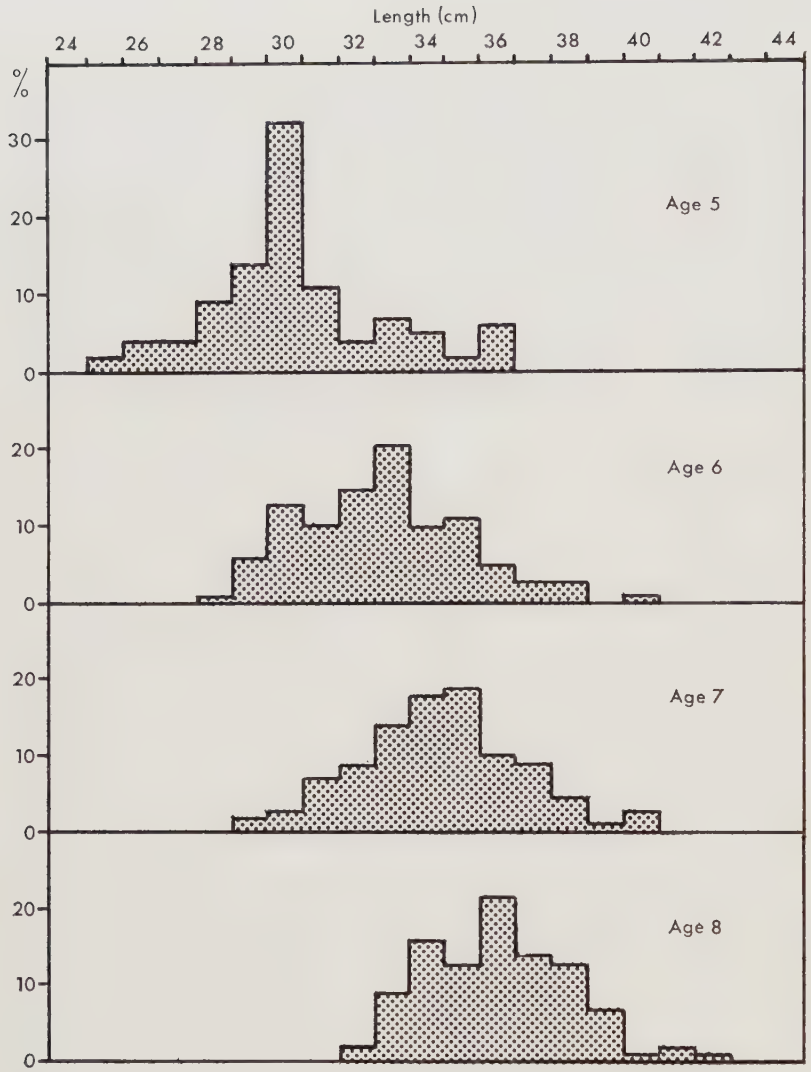


Fig. 8: Length composition of age groups 5 to 8.

Since the sex ratio of the more abundant age groups was even, the overall growth pattern is approximated by the intermediate curve in Fig. 7. There are two distinct growth phases: the annual rate of growth in length, indicated by the slope of the curve, is high up to the age of 4 to 5 years and decreases from then onward. The few fish that were sampled of the very incompletely represented age groups 3 and 4 are unlikely to be typical members of these age groups; so the present data contain little information on the earlier phase of rapid growth. The samples of the age groups 16 and older were extremely small (Table 5), and the data on these age groups were also excluded from further growth analysis.

Because of the difference in growth rate between the sexes, the uneven sex ratio of the samples of the more scarcely represented age groups must introduce some error in the estimates of the mean length from the combined data for each age group. Therefore the mean lengths of the age groups were also estimated by the arithmetic mean of the mean lengths of the sexes to give both sexes equal weight. The latter estimates are listed in Table 5 as L(2) and those from the combined data as L(1). The von Bertalanffy growth equation was fitted to the mean lengths of the sexes and to the L(1) and L(2) by a Ford-Walford regression (Ford 1933, Walford 1946). The regression was fitted by the least squares method. Three significant figures were used in the data, and all decimals were retained throughout the calculation. The growth equation was fitted in the

form given by Beverton and Holt (1957):

$$l_t = L_\infty (1 - e^{-K(t-t_0)}),$$

where l_t is length at time t and K, t_0, and L_∞ (the asymptotic length) are constant parameters.

Table 7 lists the estimates of the growth parameters. Since the sex ratio of the population is even and the annual mortality rate appears to be the same for both sexes, the true value of L_∞ for the population as a whole should be intermediate between the values for the sexes. However, the L_∞ estimate based on L(1) was lower, and that based on L(2) was higher than the estimates for either sex. Exclusion of the data for age groups 12 to 15, of which less than 10 fish in each age group were sampled, resulted in L_∞ estimates which were far too low, since the samples contained several males of 44 cm and a female of 53 cm. K was higher for the females than for the males when ages 5 to 15 years were considered, but the reverse was found for ages 5 to 11 years. Thus, though a Ford-Walford regression fitted most sets of data well (Table 7, Fig. 9), there is much inconsistency in the estimates of the growth parameters and no firm description of the growth can be given at present. If for practical purposes it has to be assumed that a constant growth pattern exists, the mean of the L_∞ estimates based on L(1) and L(2) for ages 5 to 15 years, which is 50.3 cm, may be used as a reasonable approxim-

TABLE 7: Values of the parameters K and L_∞ (in cm) of the von Bertalanffy growth equation

	r	K	L_∞
Age groups 5-15			
Total, L(1)	0.976	0.147	45.8
Total, L(2)	0.970	0.079	54.8
Females	0.978	0.110	52.9
Males	0.901	0.086	50.0
Age groups 5-11			
Total, L(1)	0.991	0.298	39.8
Females	0.981	0.227	44.0
Males	0.745	0.491	36.5

r : Correlation coefficient of the Ford-Walford regression. For explanation of L(1) and L(2) see page 20.

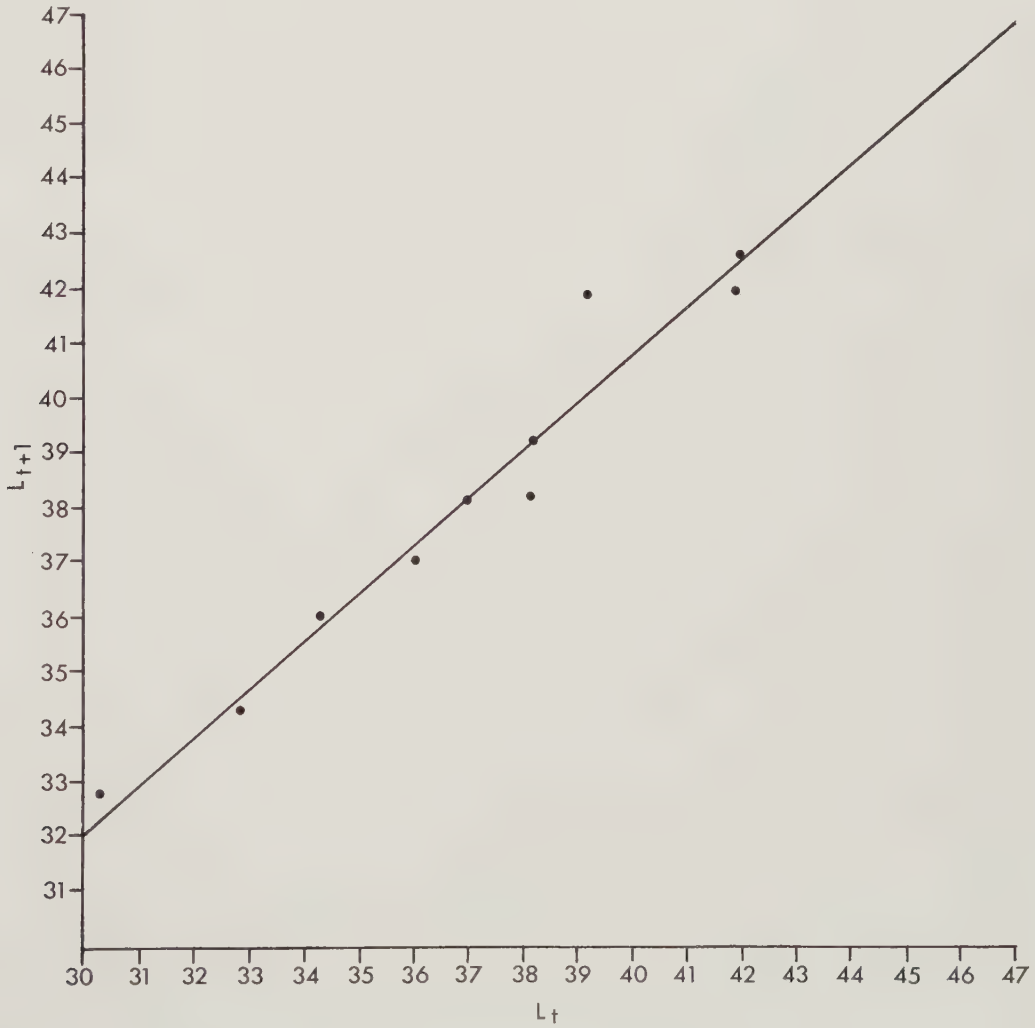


Fig. 9: Regression of l_{t+1} on l_t for age groups 5 to 15.

ation. It is about the same as the greatest fish lengths observed in the samples and is intermediate between the estimates for males and females. Thus, the following estimates are obtained:

$$L_\infty = 50.3 \text{ cm}$$
$$K = 0.1$$
$$t_0 = -4.3 \text{ years}$$

The estimate of K is the mean of the estimates from L(1) and L(2). The t_0 estimate is the mean of the estimates for the younger but fully recruited age groups, as recommended by Gulland (1965). The individual estimates of t_0 showed little variation from the mean (Table 8).

No data on body weight were collected during the present survey; so no direct estimate of W_∞ (the asymptotic weight) could be made. An equation expressing the length-weight relationship of tarakihi in autumn was, however, found in March 1969 in the Bay of Plenty (Vooren 1972):

$$W_t = 0.0141 \times l_t^{3.0869}$$

Substituting the value of L_∞ in this equation results in

$$W_\infty = 2{,}521 \text{ g.}$$

The mean weight for each age group was determined in the same way, the means of L(1) and L(2) (Table 5) being used.

TABLE 8: Individual estimates and mean of t_0, assuming $K = 0.1$ and $L_\infty = 50.3$ cm

Age group	t_0
5	−4.2
6	−4.5
7	−4.4
8	−4.5
9	−4.2
10	−4.0
Mean	−4.3

SPAWNING

Because the results of the maturity stage analysis were very similar for all stations, the data were combined, weighted by the catch per hour (Fig. 10). Stage 4 males and females dominated the catches, with only a few running ripe fish (stage 5) present, a situation found only during the tarakihi spawning period (Tong 1972a). Stage 3 males were present in large numbers, but, as spawning was in progress, this may be a reflection of partial spawning in males, since the quantity of milt is the main criterion when classifying the testes according to maturity stages (Tong 1972a).

Partially spawned females were also present in the catches. Histological observations on fish with stage 4 ovaries showed that 64 percent of these fish had recently spawned; the ovaries contained large numbers of evacuated follicles. These same ovaries also contained numerous developing eggs, which indicated further spawning. It cannot be assumed, however, that fish without evacuated follicles in the ovaries have not spawned, since these structures are thought to disappear rapidly (Tong 1972b).

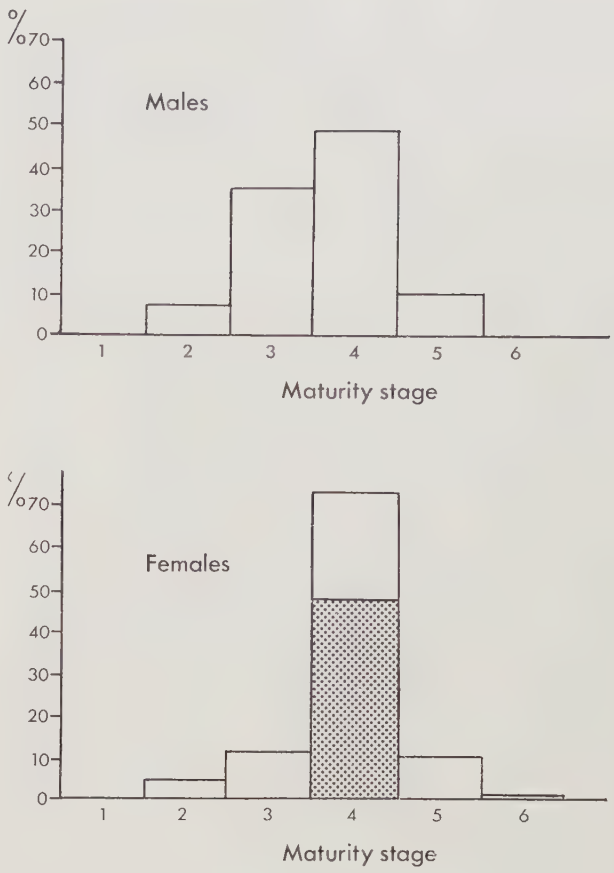


Fig. 10: Frequency distribution of maturity stages, from the weighted combined data for all catches. The stippled area shows the proportion of stage 4 females with evacuated follicles.

AGE AND LENGTH AT FIRST MATURITY

Of 1,271 tarakihi 4.3 percent were immature; 1,252 were of legal size, that is, 25 cm or larger, of which 3.0 percent were immature. The percentage of immature fish in relation to length and age groups is recorded in Tables 9A and 9B respectively.

TABLE 9A: Relationship between length and maturity

	Males			Females		
	Immature		Mature	Immature		Mature
L	No.	%	No.	No.	%	No.
20	2	100	0	2	100	0
21	3	100	0	1	100	0
22	1	100	0	3	100	0
23	0	0	0	1	50	1
24	2	100	0	2	67	1
25	2	100	0	1	33	2
26	2	67	1	2	40	3
27	0	0	4	1	16.1	5
28	1	8.3	11	4	40	6
29	3	15.0	17	5	33	10
30	3	7.7	36	2	6.7	28
31	1	1.7	59	1	3.3	29
32	0	0	82	4	7.7	48
33	1	1.2	81	2	2.5	79
34	0	0	92	2	3.3	59
35	0	0	57	0	0	78
36	1	1.9	53	0	0	66
37	0	0	34	0	0	70
38	0	0	15	0	0	57
39	0	0	16	0	0	31
40	0	0	9	0	0	23
41	0	0	12	0	0	41
Total	22		579	33		637

L : Fish length (cm).

The smallest mature tarakihi was a female of 23 cm, aged 4 years. No fish were mature at 3 years and most fish of 6 years and over were mature, except for two females of ages 7 and 8 years. Since the juvenile and immature portions of the stock were not fully sampled, no conclusive data on the age and length at first maturity are available. However, Tables 9A and 9B and the data on age frequency (Fig. 4) indicate that fish generally mature between the ages of 4 and 6 years and between the lengths of 23 and 36 cm. Similar results were obtained in the Bay of Plenty (Tong 1972a), but males there appear to mature at an earlier age and smaller size than females. The present data indicate that in the East Cape area males and females mature at the same age and length.

TABLE 9B: Relationship between age and maturity

	Males			Females		
	Immature		Mature	Immature		Mature
Age	No.	%	No.	No.	%	No.
3	4	100	0	2	100	0
4	1	12.5	7	4	33.3	8
5	6	22.2	21	3	12.5	21
6	1	1.0	101	6	5.8	98
7	0	0	90	1	1.0	99
8	0	0	23	1	2.4	40
9	0	0	45	0	0	73
Total	12		287	17		339

DISCUSSION

Cassie (1955) states that the length/girth ratio of the tarakihi is 1.25 if length is measured as was done in the present investigation. He found that about 50 percent of snapper (*Chrysophrys auratus* Forster) with a girth equal to the circumference of the cod-end mesh were retained by a trawl, and of those with a girth exceeding the circumference of the cod-end mesh by 2.5 cm about 90 percent were retained. The legal minimum size of the cod-end mesh of trawls in New Zealand is 10 cm (New Zealand Marine Department 1939), but most trawlers use nets with a cod-end mesh of 11.3 cm (Fisheries Research Division unpublished data). If the findings for snapper apply to tarakihi, there is 50 percent retention by a trawl with a cod-end mesh of 11.3 cm at a fish length of 28 cm and almost full retention at a length of 31 cm. This implies that a large proportion of the 5-year-olds and even some of the 6-year-olds on the fishing grounds would not be vulnerable, and there would be full recruitment at the age of 7 years. Whether or not this is really so cannot be decided at present, since there is no information on mesh selection in the tarakihi. A comparison between the length frequency of the combined catches in the present survey and the mean length frequency of three commercial catches near Cape Runaway in March 1970 taken by a trawl with a cod-end mesh of 11.3 cm (Fisheries Research Division unpublished data) suggests that the large commercial mesh may retain many, if not most, of the smaller fish, both length-frequency distributions being almost identical (Fig. 6). There would then be partial recruitment at the age of 5 years and full recruitment at the age of 6 or 7 years, depending on whether age group 6 is normally completely present on the fishing grounds.

Beverton and Holt (1959) list estimates of K (one of the growth constants) and M (the instantaneous coefficient in natural mortality) for a large number of fish stocks belonging to various species. The value of K found for tarakihi in the East Cape area is low in comparison with most values listed, but is about that found for several Gadiformes, Pleuronectoidei, and Salmonoidea. Beverton and Holt (1959) have also shown that low values of K tend to be associated with low values of M, so that in the recruited phase of the tarakihi M may be low, for instance, about 0.12 to 0.22, which are the values quoted for females and males of *Pleuronectes platessa* L. respectively. The lifespan of the latter species is quoted as 22 years in the females, which is about the same as was observed in tarakihi; the oldest fish found in the East Cape area was 27 years old.

The large deviation from zero of t_0 illustrates that the growth equation found provides only a description of the later phase of slow growth and not of the whole growth pattern: under the present values of the growth parameters, l_t at $t = 0$ would be 17.6 cm. In such a case the equation can still be used validly in studies of the recruited phase (Beverton and Holt 1957).

The estimates of the growth parameters and the conclusions on recruitment pattern, sex ratio, and sexual differences in growth presented here are to be regarded as tentative. As such they are useful for orientation and will provide a basis for a preliminary analysis of the fishery. Stock surveys similar to the one described are planned for future years in order to follow the developments in the tarakihi stock, to refine the measurements of the various parameters, and to verify the assumptions and conclusions presented in this bulletin.

SUMMARY

A trawl survey of the tarakihi stock in the East Cape area was made in March 1971. The species occurred mainly at depths between 90 and 160 m, with a density of 6.31 fish per hectare of swept area. The age composition of the catches indicated that recruitment to the adult stock begins at the age of 5 years and is complete at 7 years; the pattern is similar for both sexes. The sex ratio of the population as a whole is 1:1, though individual catches showed distinct variation. There are two growth phases: the growth rate is rapid until the age of 5 years and is much slower thereafter. In the second phase the growth patterns of the sexes differ. A von Bertalanffy growth equation was fitted to the second phase. The estimates of the growth parameters for both sexes combined are: $K = 0.1$, $t_0 = -4.3$ years, $L_\infty = 50.3$ cm, $W_\infty = 2{,}521$ g. The low value of K indicates that the natural mortality rate may be low. Maturing, recently spawned, and ripe fish dominated all catches, which indicated that spawning was in progress.

REFERENCES

BEVERTON, R. J. H., and HOLT, S. J. 1957: On the dynamics of exploited fish populations. *Fishery Invest., Lond., Ser. 2,* 19. 533 pp.

——— 1959: A review of the lifespans and mortality rates of fish in nature, and their relation to growth and other physiological characteristics. *Ciba Fdn Colloq. Ageing 5:* 142-80.

CASSIE, R. M. 1955: The escapement of small fish from trawl nets and its application to the management of the New Zealand snapper fisheries. *Fish. Bull. N.Z. 11.* 99 pp.

FORD, E. 1933: An account of the herring investigations conducted at Plymouth during the years from 1924 to 1933. *J. mar. biol. Ass. U.K. 19:* 305-84.

GULLAND, J. A. 1955: Estimation of growth and mortality in commercial fish populations. *Fishery Invest., Lond., Ser. 2, 18 (9).* 46 pp.

——— 1965: Manual of methods for fish stock assessment. Part 1. Fish population analysis. *F.A.O. Fish. tech. Pap. 40, Revision 1.* 66 pp.

MCKENZIE, M. K. 1961: Fisheries research in the East Cape area. *Fish. tech. Rep. N.Z. mar. Dep. 3.* 9 pp.

NEW ZEALAND MARINE DEPARTMENT. 1939: "The Sea-fisheries Regulations 1939." Government Printer, Wellington. 39 pp.

PEARSON, E. S., and HARTLEY, H. O. (Eds.). 1954: "Biometrika Tables for Statisticians", Vol. I. University Press, Cambridge. 238 pp.

PINHORN, A. T., and FLEMING, A. M. 1965: A comparison of random and stratified sampling methods for age and growth studies in the Newfoundland inshore cod fishery. *Res. Bull. int. Commn NW. Atlant. Fish. 2:* 25-30.

RICKER, W. E. 1958: Handbook of computations for biological statistics of fish populations. *Bull. Fish. Res. Bd Can. 119.* 300 pp.

TONG, L. J. 1972a: Breeding biology. *In* Tong, L. J., and Vooren, C. M., The biology of the New Zealand tarakihi, *Cheilodactylus macropterus* (Bloch and Schneider), pp. 35–45. *Fish. Res. Bull. (N.Z.) 6.*

——— 1972b: Gametogenesis. *In* Tong, L. J., and Vooren, C. M., The biology of the New Zealand tarakihi, *Cheilodactylus macropterus* (Bloch and Schneider), pp. 46–55. *Fish. Res. Bull (N.Z.) 6.*

TONG, L. J., and ELDER, R. D. 1968: Distribution and abundance of demersal fish from trawl stations in the Bay of Plenty, New Zealand, 1961–63. *N.Z. Jl mar. Freshwat. Res. 2:* 49-66.

VOOREN, C. M. 1972: Age and growth. *In* Tong, L. J., and Vooren, C. M., The biology of the New Zealand tarakihi, *Cheilodactylus macropterus* (Bloch and Schneider), pp. 28–34. *Fish. Res. Bull (N.Z.) 6.*

——— (in press): An analysis of the statistics on the fishery for tarakihi, *Cheilodactylus macropterus* (Bloch and Schneider), in New Zealand waters, from 1936 to 1969, with notes on the trawl fishery in general. *Fish. Res. Bull. (N.Z.) 7.*

VOOREN, C. M., and TONG, L. J. 1972: Age determination. *In* Tong, L. J., and Vooren, C. M., The biology of the New Zealand tarakihi, *Cheilodactylus macropterus* (Bloch and Schneider), pp. 13–27. *Fish. Res. Bull. (N.Z.) 6.*

WALFORD, L. A. 1946: A new graphic method of describing the growth of animals. *Biol. Bull. mar. biol. Lab., Woods Hole, 90:* 141-7.

INDEX

Age and length at first maturity, 24.
Age composition, 11, 12, 15–17, 18.
Age determination, 12, 15, 19.
Age-frequency distribution, 15, 17, 24.
Age-maturity relationship, 24.
Annual growth rate, 12, 19–22.
Annual mortality rate, 12, 17, 18, 19, 21.
Arripis trutta, 14.

Barracouta, 13, 14.
Bay of Plenty, 12, 13, 17, 18, 19, 22, 24.

Cape Runaway, 9, 15, 25.
Caranx lutescens, 14.
Catch rate and bottom temperature, 14.
Catch rate and density index, 12, 14.
Catch rate and depth relationship, 13, 14.
Chelidonichthys kumu, 14.
Chrysophrys auratus, 14, 25.
Cod-end mesh sizes, 11, 25.
Continental Shelf, 9, 11.

Deep zone, 10, 11, 12, 13, 14.
Density index of age groups, 12, 18.
Distribution and abundance of species, 13–14.

Ford-Walford regression, 20, 21.
Frequency distribution of maturity stages, 23.
Frostfish, 14.

Gadiformes, 25.
Galeorhinus australis, 14.
Growth, 19–22.

Hawke Bay, southern, 17.
Horse mackerel, 13, 14.

Instantaneous mortality rate, 12, 25.

James Cook, 11.
Jordanidia solandri, 14.
Juveniles, 17, 24.

Kahawai, 14.

Length composition, 11, 20.
Length-frequency distributions, 19, 25.
Length/girth ratio, 25.
Length-maturity relationship, 24.
Length, mean, of age groups, 18, 19, 20.
Length-weight relationship, 22.
Lepidopus caudatus, 14.

Mahia Peninsula, 9.
Maturity stages, frequency distribution of, 23.
Methods and definitions, 11–12.
Mortality rate, annual, 12, 17, 18, 19, 21.

Otoliths, 12, 19.

Pleuronectes platessa, 25.
Pleuronectoidei, 25.

Ranfurly Bank, 11, 17.
Recruitment, 12, 15, 25.
Red gurnard, 14.

Salmonoidea, 25.
Sampling, 11–12.
School shark, 14.
Seriola grandis, 14.
Sex ratio, 17, 18, 19, 20, 21, 25.
Shallow zone, 11, 12, 13, 14.
Snapper, 13, 14, 25.
Southern kingfish, 14.
Spawning, 9, 12, 23.
Subzones, 10, 12, 13, 14.

Thyrsites atun, 14.
Trachurus novaezelandiae, 14.
Trawl stations, 10, 11, 12, 13, 14, 15.
Trevally, 13, 14.

von Bertalanffy growth equation, 20, 21.
Vulnerability, 12, 25.

Weight, mean, of age groups, 18, 22.

Yellowtail, 14.

Bulletins of the Fisheries Research Division

1. The New Zealand Cetacea. By D. E. Gaskin. Published in 1968. 92 pp.

2. *Galaxias maculatus* (Jenyns), the New Zealand whitebait. By R. M. McDowall. Published in 1968. 84 pp.

3. Phytoplankton productivity in Tomahawk Lagoon, Lake Waipori, and Lake Mahinerangi. By S. F. Mitchell. Published in 1971. 87 pp.

4. Some aspects of the bionomics of fish in a brown trout nursery stream. By C. L. Hopkins. Published in 1970. 38 pp.

5. Reproduction, early life history, and age-growth relationships of the New Zealand pilchard, *Sardinops neopilchardus* (Steindachner). By Alan N. Baker. Published in 1972. 64 pp.

6. The biology of the New Zealand tarakihi, *Cheilodactylus macropterus* (Bloch and Schneider). By L. J. Tong and C. M. Vooren. Published in 1972. 60 pp.

7. An analysis of the statistics on the fishery for tarakihi, *Cheilodactylus macropterus* (Bloch and Schneider), in New Zealand waters from 1936 to 1969, with notes on the trawl fishery in general. By C. M. Vooren (in press).

8. Lakes Rotorua and Rotoiti, North Island, New Zealand: Their trophic status and studies for a nutrient budget. By G. R. Fish (in press).

9. A survey of the tarakihi, *Cheilodactylus macropterus* (Bloch and Schneider), in the East Cape area, New Zealand, 26-30 March 1971. By C. M. Vooren and L. J. Tong. Published in 1973. 28 pp.

10. The relation between primary productivity, nutrients, and the trout environment in some New Zealand lakes. By A. M. R. Burnet and Denise A. Wallace (in press).